U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

AD-A036 235

THE PRESENT STATUS OF PHYSICAL FITNESS IN THE AIR FORCE

SCHOOL OF AVIATION MEDICINE
RANDOLPH AIR FORCE BASE, TEXAS

MAY 1959

1

THE PRESENT STATUS OF PHYSICAL FITNESS IN THE AIR FORCE

BRUNO BALKE, M. D.
RAY W. WARE, Captain, USAF (MC)

Department of Physiology and Biophysics

D.
6-24-59

59-67

Air University
SCHOOL OF AVIATION MEDICINE, USAF
RANDOLPH AFB, TEXAS
May 1959

7758-103

THE PRESENT STATUS OF PHYSICAL FITNESS IN THE AIR FORCE

Work capacity, a sensitive and realistic measure of "physical fitness," was determined on more than 500 military and civilian Air Force personnel for the purpose of collecting material for the standardization of physical performance capacity. A treadmill test permitted an evaluation of results in physical as well as in physiologic terms. On the basis of results, physiologic considerations, and observations of men at various stages of physical training, an arbitrary rating scale of work capacity is suggested. According to this pilot study 42 percent of the test population had to be rated as "poor" and 40 percent as "fair." Only 18 percent could be considered as having a "good" or better physical condition. Sedentary living habits, more than aging or other factors, were apparently the main antagonists of good physical fitness.

The modern way of highly civilized life has almost completely removed the necessity for greater physical efforts. Automation in labor, in transportation, and in many activities of daily living has greatly reduced the need for physical exercise, as was previously required. As a consequence, the great functional reserves of the human organism, provided by nature, may become seriously affected since the organs are readily adaptable to changes of functional demands. Regular physical activity enlarges metabolic, circulatory, and respiratory reserves while inactivity has the opposite effect. Although high functional reserves have never been found to be undesirable, the sedentary man insists that he can easily live without them. It is not known, however, to what extent the reserves may diminish through the years without ill effects on the man's well-being. And not much is known about the normal range of capacity for coping with increased metabolic demands. Standards of "physical fitness" are lacking because "fitness" has never been clearly defined and, therefore, is not measurable.

It is generally understood that a high level of "physical fitness" enables an individual to meet strenuous physical demands with the least strain of functional efforts and with fewer consequences of physical fatigue. Since the physiologic reactions to work are measurable and a determination of the functional limitations is possible with a sufficient degree of accuracy, an appraisal of the physical performance capacity of an individual appears to be feasible. Work capacity could be defined as the highest level of metabolic load which can be compensated for adequately by optimal coordination of the functional reserves. This definition of work capacity is based on experimental evidence that in gradually increased work a point will eventually be reached at which definite physiologic limitations result in a failure to adequately meet further metabolic requirements. These functional limitations may be of cardiovascular, respiratory, metabolic, or hormonal nature.

The most objective criterion of work capacity, as defined, is the maximal oxygen consumption as a measure of circulatory and respiratory adaptability. On the basis of this criterion, P.O. Astrand (1) has determined work capacity of a rather large group of individuals and has correlated the results with sex and age. The main body of his experimental subjects was composed of Swedish physical education students and the results of the study reflect, accordingly, a relatively high level of performance capacity. U. C. Luft (2), in a clinical study, determined the physical competence of male outpatients from 20 to 45 years of age. All were in good health, according to rigorous clinical standards, but not accustomed to occupational or recreational physical exercise. The results, therefore, reflect a relatively low level of work capacity.

Received for publication on 2 February 1959.

To fill an existing gap in knowledge and to obtain more information about the normal range of physical performance capacity in man, a study was initiated to screen the work capacity of a large population. This report presents the experimental results of the first series of investigations of approximately 500 male military and civilian Air Force personnel.

METHOD

The method of screening work capacity was developed in this laboratory and has proved a useful tool in evaluating changes in work capacity brought about by changes in physiologic or environmental situations (3,4,5). The test on the treadmill or bicycle-ergometer begins with light work requiring an energy expenditure of not more than four times the resting rate. That is accomplished, on the treadmill, by walking at a speed of 90 meters per minute (or at 3.3 m.p.h.) on a horizontal level. Every minute a light load is added by elevating the treadmill angle 1 percent. The increase of work intensity is so gradual that functional adaptations take place within a few seconds. Thus, there is hardly any difference between the functional values measured during any given minute of this test and the values measured during "steady-state work" at comparable gradients.

The adaptive functional response to the gradually increased metabolic requirements is assessed by cardiovascular and respiratory measurements. Previous studies have shown that the attainment of a pulse rate of 180 beats per minute may serve as the critical cut-off point for this test. Although *maximal* work capacity usually reaches well beyond this point, there are sufficient physiologic indications to validate this criterion as a useful measure of the aerobic crest load. A continuation of work beyond this point is, in most instances, not paralleled by further adequate functional adaptation. Work, then, becomes increasingly anaerobic.

The maximal oxygen intake measured at the cut-off point of this testing procedure is generally somewhat lower than the values determined by the usual procedure of employing work of 6 minutes' duration at a constant maximal load. However, it might more closely represent the maximal oxygen intake which can be maintained for longer periods of time and, therefore, may express more appropriately the capacity for sustained work.

In a relatively small number of cases the test cannot be carried on to a pulse rate of 180 beats per minute. Occasionally, obvious respiratory limitations or a nonreversible reduction of the blood pressure amplitude occur at lower pulse frequencies and serve as indications to terminate the test. In men of advanced age the maximal pulse frequency rarely reaches 180 beats per minute (6, 7).

PROCEDURE

After arrival at the laboratory the experimental subjects were accustomed to walking on the treadmill until their stride became normal and relaxed. They then answered a short questionnaire as to age, rank, present job, previous and present physical activities, and smoking habits and whether or not they favored a regular physical training program. Weight and height were measured and the subjects were then readied for the test.

Pulse rate and blood pressure measurements were taken before and after the test at sitting rest, and while walking on the treadmill during the second half of each minute. Determinations of respiratory gas exchange during work were made at regular intervals. The work intensity was gradually increased by elevating the treadmill angle 1 percent each minute.

RESULTS

For quick orientation, the test duration in minutes, identical with the final treadmill grade in percent, can serve as a readily available criterion of work capacity. On the basis of this criterion the test results from more than 500 subjects were plotted. As shown in figure 1, individuals in the poorest physical condition attained a critical pulse rate of 180 beats per minute as early as the seventh or eighth test minute, the average performance centering around the fifteenth and sixteenth minute; and

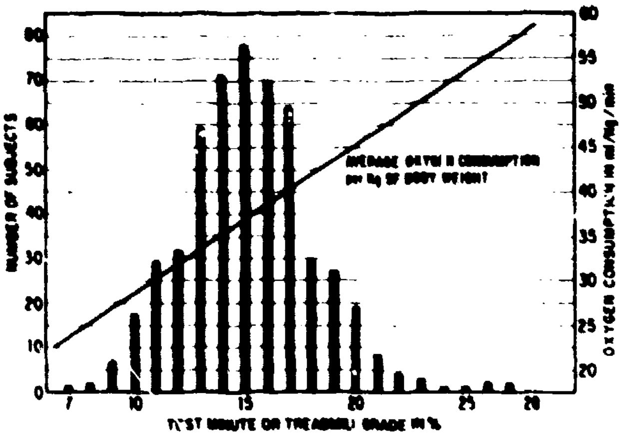

FIGURE 1

General distribution of the work capacity of 530 male individuals, based on critical test duration or treadmill elevation, and related to the maximum oxygen consumption.

some individuals, in excellent physical condition, were able to last longer than 23 minutes before reaching the cut-off point. Exceedingly well-trained athletes (members of the U.S. Pentathlon Team) set the highest marks with 27 and 28 minutes.

Based on the measurements of the gas exchange during the test work, the average metabolic requirements for the gradually increased work were superimposed on the graph as oxygen consumption per kilogram of body weight per minute in order to demonstrate the correlation between the test duration and the physiologic demands of the corresponding loads.

Cardiovascular response

Of all the physiologic functions measured, the pulse rate at any given work load reflected most closely the status of the work capacity of an individual. Figure 2 illustrates the pulse response patterns of four groups of individuals: the work capacity of group I was classified as "very poor," that of group II as "fair," that of group III as "very good," and that of group IV as "superior." There was a considerable overlapping of the individual values at the lower work load levels; hence, the use of any pulse rate below 180 beats per minute as a critical cut-off point for determining work capacity appears less reliable. Most individuals not accustomed to strenuous physical effort display a variety of reaction patterns in their functional adaptation to gradually increasing work until they approach cardiovascular limitations.

When blood pressure values, observed at the various work intensities, were averaged and plotted, certain trends became apparent: the individuals with lower work capacity had, on the average, higher systolic as well as higher diastolic pressures at comparable loads than individuals with higher physical performance capacity. The maximal systolic pressures, however, were for all groups almost identical. Despite these apparent trends, the use of the blood pressure as a criterion for individual differentiation of work capacity is unsatisfactory because of the tremendous overlapping of the individual values. The only statement which can be made with some degree of validity is that high diastolic pressures (100 mm. Hg and above) usually designate low levels of work capacity, while very low diastolic pressures (from 60 mm. Hg down to zero) are most likely to be observed in individuals with high performance capacity.

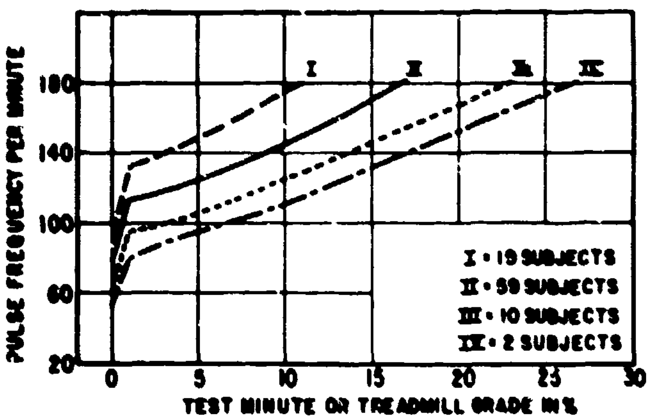

FIGURE 2

Pattern of typical pulse response to gradually increased demands during the work capacity test. Groups I to IV represent very poor, fair, very good, and superior "physical fitness," respectively (see table I).

Oxygen consumption

One might assume that an individual's work efficiency (that is, the amount of oxygen consumed per unit of body mass at a given work load) would be of valuable assistance in determining work capacity. Such a criterion, however, was found to be impractical. Although group averages revealed a noticeable trend toward slightly decreased oxygen intake as performance capacity increased (fig. 3), the overlap of individual values excludes the general use of this criterion in individual evaluation of work capacity. In fact, the real differences in the efficiency of walking are so small from man to man, and the correlation between work intensity and oxygen requirement per unit of body mass is so well established, that one is able to predict an individual's total oxygen intake for a known work intensity. The following linear equation proved to approximate very closely the average values of oxygen intake measured during the treadmill test:

$$\dot{V}_{t} = v \times w \times \left(0.073 + \frac{a}{100}\right) \times 1.8$$

where

$\dot{V}_{t}$ = the oxygen consumption in milliliters per minute (STPD)

v = the treadmill speed in meters per minute

w = the body weight in kilograms

a = the treadmill angle in percent

1.8 = the factor constituting the oxygen requirement in milliliters per minute for 1 kgm. of work.

Considering the maximal oxygen consumption as the most satisfactory means of describing work capacity the oxygen intake at the "crest load," expressed in milliliters per kilogram per minute, might be preferred as a functional criterion of physical performance capacity to either the time or the treadmill grade of the critical test minute. In table I an attempt is made to correlate the results demonstrated in figures 1 and 3 with a suggested rating of physical working capacity. The rating scale is based on the results from the test population, on physiologic considerations, and on observations of men at various stages of physical training.

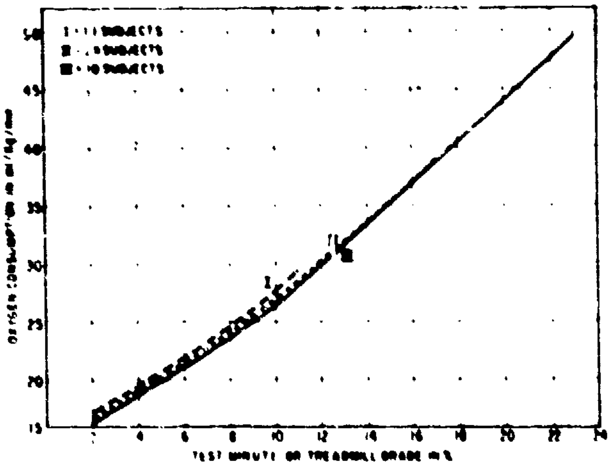

FIGURE 3

Average oxygen consumption (per unit of body weight) during the work capacity test. The work efficiency of the group in "very poor" condition (I) appears to be only little less than that of the "fair to good" (II) or the "very good" group (III).

Pulmonary ventilation

While work efficiency estimated from the oxygen consumption proved an impractical criterion of work capacity, the efficiency of breathing appeared more closely related to "physical fitness." Figure 4 clearly demonstrates that, on the average, the physically well-conditioned individual moves less air at comparable work intensities. That means, since the oxygen consumption is practically identical, that the extraction rate of oxygen from the inspired air is greater in the more physically fit man and, in turn, the fraction of carbon dioxide in the expired air is also greater.

In addition to such qualitative differences, the same figure demonstrates quantitative differences: the "maximal breathing capacity during work" attains higher values with progressing physical performance capacity.

TABLE I

Rating of work capacity in correlation with maximal oxygen intake or metabolic rate, or with the test duration

Rating of work capacity	Oxygen intake (ml./kg./min.)	Multiples of resting metabolic rate	Test duration (min.)
Inferior	< 25	< 7	< 8
Very poor	25 - 30	7 - 8	8 - 11
Poor	30 - 35	8 - 9	12 - 14
Fair	35 - 40	10	15 - 17
Good	40 - 45	11 - 12	18 - 20
Very good	45 - 50	13	21 - 23
Excellent	50 - 55	14 - 15	24 - 26
Superior	55 +	15 +	27 +

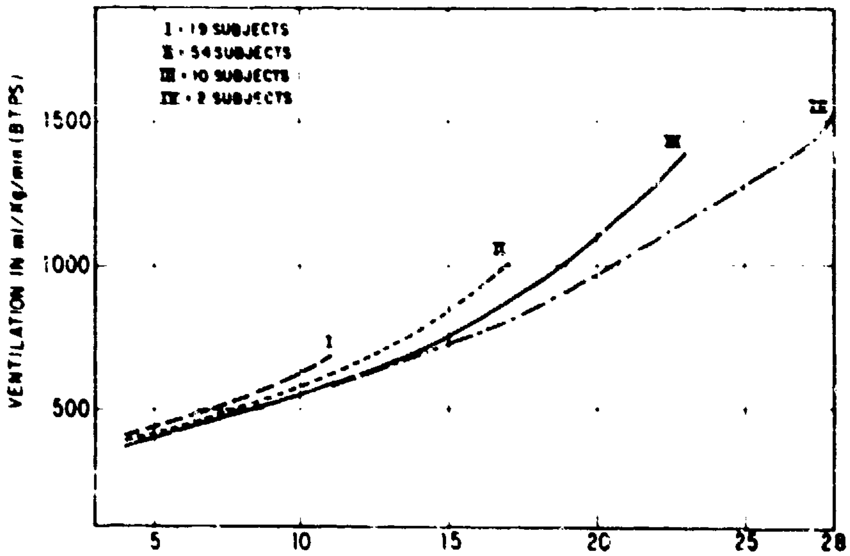

FIGURE 4

Pulmonary ventilation (per unit of body weight) serves as a somewhat better indicator of work efficiency than oxygen consumption. Greater work capacity is associated with a greater respiratory efficiency and, usually, with a greater maximal breathing capacity.

GENERAL OBSERVATIONS

Factors such as age, activity, weight, and personal habits were shown to have some effect on the work capacity of the test population.

Age and physical activity

It is a common belief that "aging" leads to a progressive deterioration of physical working capacity. Although the decrease of speed, elasticity, and muscular strength, of oxygen debt capacity, and of several other parameters of functional capabilities appear well established, it is also known that some older men can be surprisingly efficient in activities such as farming or other occupational outdoor work, in hiking, climbing, skiing, and even in sports such as tennis and fencing, which require considerable skill.

The present experimental study has demonstrated that aerobic work capacity is not inevitably affected by age, but is far more affected by living habits. In our scrutiny of the replies of 455 subjects to the question regarding physical activities, 149 individuals, or 33 percent, had to be regarded as living a strictly sedentary life; 260 individuals, or 57 percent, engaged "intermittently" in some sort of sports or outdoor work; and only 46 subjects, or 10 percent, considered themselves as regularly active in any kind of physical exercise.

Distribution of the individual test results (fig. 5) reveals a poor average performance for the sedentary group, a poor to fair level of work capacity for the intermittently active group, and good functional reserves for the group with regular physical activity.

The results for the first two groups support the general opinion that work capacity is reduced as age advances (fig. 6), but results for the group with regular physical activity demonstrate that a high level of capacity for aerobic work can be maintained as one grows older (fig. 7). This latter group includes individuals in the age range from 22 to 65 years, the average being 36 years.

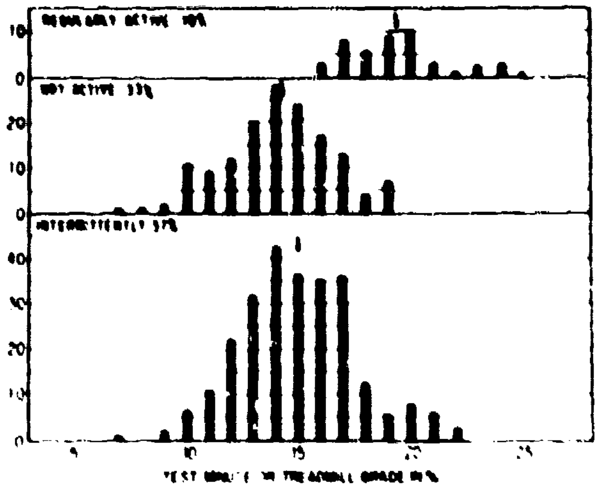

FIGURE 5

Distribution of the individual test results as related to physically active or inactive living habits. Arrows indicate group averages.

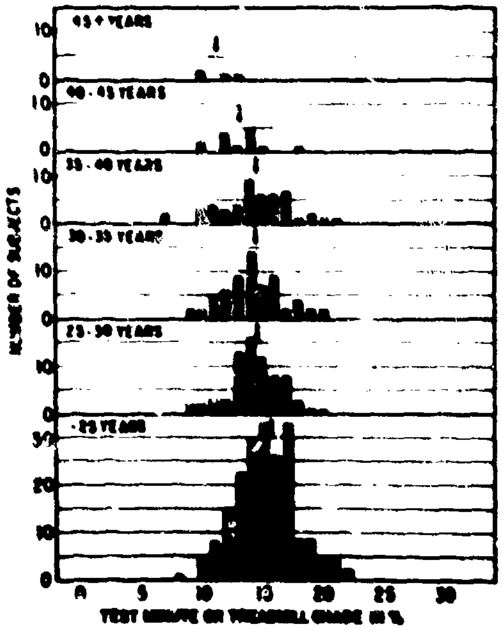

FIGURE 6

Distribution of work capacity of the test population with more sedentary living habits, according to various age groups.

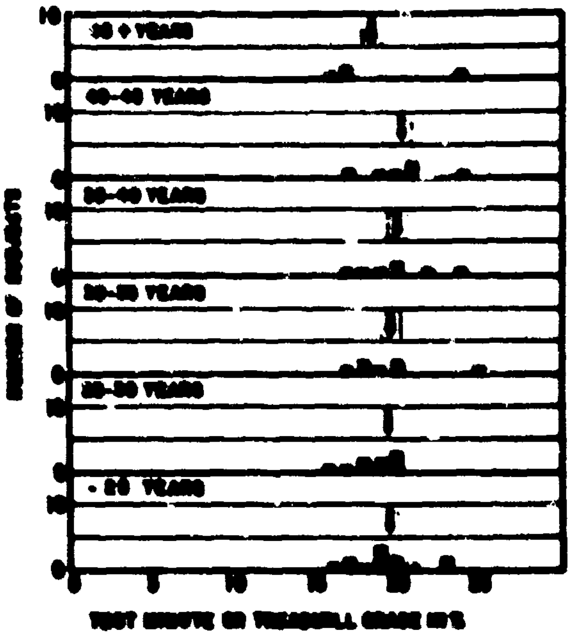

FIGURE 7

Distribution of work capacity, according to age groups, of the test population with regular physical activity.

Body weight

The test population was divided into the groups of "normal," "underweight," and "overweight" individuals. The following crude yardstick was used to make this differentiation: the weight was considered as "normal" within 90 to 100 percent of the total body length in centimeters minus 100 cm. For example, a man who measured 182 cm. in height (6 ft.) was considered as having a "normal" weight within the range of 74 to 82 kg., which is between 90 to 100 percent of 82 (182 cm. minus 100). "Underweight" or "overweight" was indicated when a man of the same height weighed less than 74 kg. or more than 82 kg., respectively.

Figure 8 illustrates the slight handicap of the overweight type who, on the average, had a poor work capacity while the normal and underweight men were somewhat better off.

Of the 455 individuals tested, 33 percent were declared overweight and, contrary to our expectations, 25 percent had to be considered underweight — according to the standard used.

Performance in relation to rank and duty

When the entire test population was divided into the four subgroups — officers, noncommissioned officers, airmen, and civilian personnel — slight differences in the functional reserves between the groups were detected. Civilian personnel and airmen had a slight edge with 15.6 and 15.1 minutes of average test duration, officers averaged 14.9 minutes, and noncommissioned officers, 14.5 minutes (fig. 9). For these groups the average maximal oxygen intake per kilogram of body weight was 38, 37.5, 36.7, and 36 ml. per minute, respectively. In the officer group, from second lieutenant to colonel, there were practically no variations. This finding is probably somewhat unrealistic because in the higher ranks the experimental subjects were strictly volunteers while the lower ranking officers were mainly selected at random. Volunteers for a physical performance test are usually individuals with greater interest in occasional or more regular physical activity.

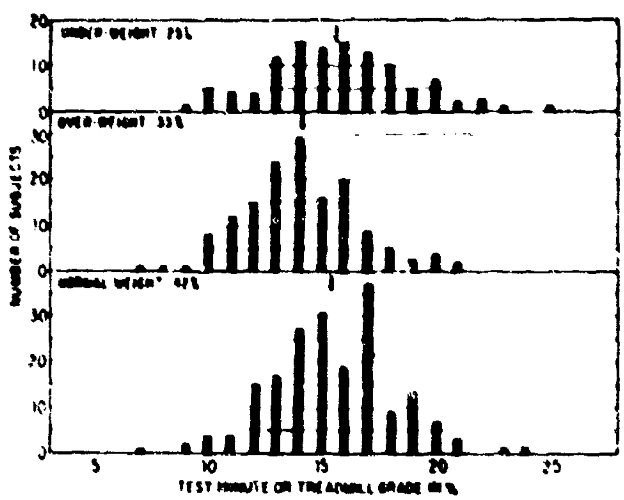

FIGURE 8

Distribution of work capacity as related to the factor of weight.

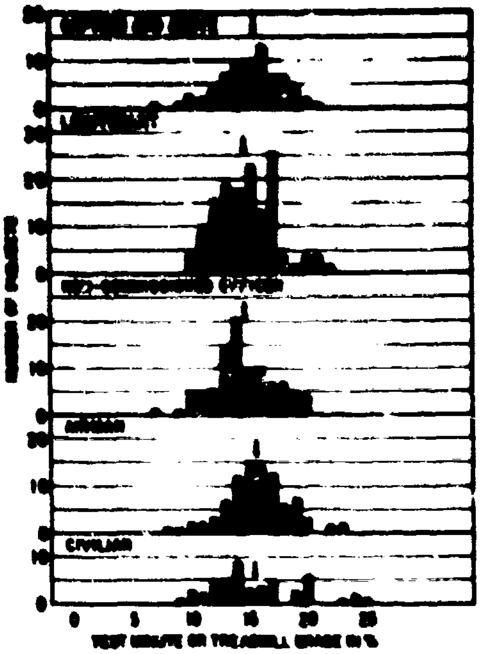

FIGURE 9

Distribution of work capacity as related to military rank.

Evaluation of work capacity and smoking habits

An attempt was made to evaluate differences in work capacity as a consequence of smoking habits. Figure 10 shows the distribution of the test results for the smokers and nonsmokers. The nonsmokers (28 percent of 455 individuals) had an average time of 15.4 minutes, which was a slight advantage over the average test time of 14.9 minutes for the smokers. On a group of 200 experimental subjects with widespread variations in age the observation was made that up to about 30 years there was no difference in work capacity between the smokers and nonsmokers. Beyond the age of 30 years, however, the nonsmokers displayed greater functional reserves. The nonsmoker is often conscientious as to healthful living habits, including physical exercise. That would explain the greater capacity for work. On the other hand, it is possible that the chronic effect of smoking affects circulatory and respiratory reserves disadvantageously.

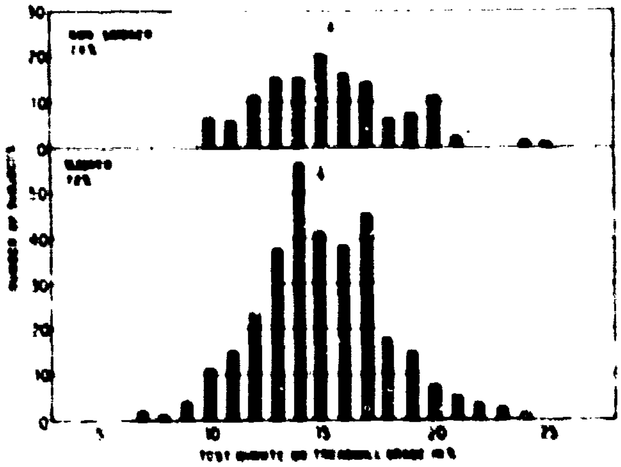

FIGURE 10

Distribution of work capacity as related to the habit of smoking.

DISCUSSION

During the last two or three years increasing attention has been focused on the shortcomings of "physical fitness" of the American younger generation compared with youth of other nations. It is disappointing that during several nationwide conferences no agreement has been reached as to a clear definition of "physical fitness." As a consequence, studies along this line meet much controversial argumentation. Everybody delights in immediately posing the questions: Physically fit? Fit for what? For shuffling papers from one side of the desk to the other?

In most minds, power today rests in ideas, in motives, in organization, and, above all, in technology. According to this thinking, the evolution of the human race should tend toward the development of a strictly cerebral-visceral type of man with more and more neglect of all the body parts and organs which, originally, were vital for survival. Unfortunately, a nation's place among the other nations and its survival in the eternal struggle between them depend largely on the general vitality of the population. History has shown that the great accomplishments of all the ancient nations were destined to perish when a peak

of civilization slowly softened the physical resistance of man against the forces of nature or against the onrush of a more vital enemy. We cannot expect this pattern to change in modern times despite all technologic advancements. Unless one does not care about the destiny of future generations, conscious and sustained efforts should be made to maintain the physical capacities of man at high standards. But what are high standards or, even, what are normal standards?

The one physical capacity which most closely determines a man's ability to withstand a variety of functional demands is his capacity for work. All environmental stresses, occupational difficulties, health hazards, etc., require proper functional and metabolic adjustments, but rarely to such an extent as strenuous physical work. It has been shown that work capacity can be appraised. The setting of "standards," therefore, is only a matter of collecting the individual performance data of a large population. The experimental work of this study was a start in that direction. Although the number of approximately 500 subjects is too small to allow for establishing a definite scale of work capacity, or "Physical Performance Capacity," or "Physical Condition," or "Physical Fitness," preliminary conclusions are experimentally justified. It became apparent from this study that 42 percent of the test population had to be rated as being in "poor" physical condition, and only 18 percent could be rated as having a "good" and better than good work capacity. The remaining 40 percent constituted the population with an average performance capacity, which was considered as "fair." This arbitrary rating might be disputable but at least it offers a quite sensitive and realistic approach to setting standards for "physical fitness." The observations made indicate: (1) the average performance capacity of individuals who live a strictly sedentary life is "poor," that of individuals who adhere to any type of physical activity intermittently is "fair," and that of regularly active individuals is "good"; (2) in the group taking part in regular physical activity, work capacity was apparently not affected by advancing age within the range of 20 to 60 years; (3) in testing 131 officers on flying status (KC-97 training program) the incidences of "poor physical fitness" were 39, 51, and 58 percent, respectively, of the test results obtained from second lieutenants, first lieutenants, captains and above. Results of experimental studies on metabolic reserves (8) indicate that these officers would have a very poor chance of survival in emergency situations requiring a higher rate of energy expenditure.

On the basis of the experimental findings it can be concluded that the over-all state of "physical fitness" in Air Force personnel is "poor" and that the Air Force physical fitness program, as it now stands, is ineffective.

REFERENCES

1. Åstrand, P.O. Experimental studies of physical working capacity. Copenhagen: Ejnar Munksgaard, 1952.
2. Luft, U.C. Personal communication.
3. Balke, B. Optimal working capacity, its measurement, and alteration as effect of physical fatigue. Arbeitsphysiologie 15:311 (1954).
4. Balke, B., G. F. Grillo, E. B. Konecci, and U. C. Luft. Work capacity after blood donation. J. Appl. Physiol. 7:231 (1954).
5. Balke, B. Work capacity at altitude. *In* Symposium of exercise and sports science. New York: Harper Bros. (In press)
6. Åstrand, I. The physical work capacity of workers. Acta physiol. scandinav. 42:73 (1958).
7. Dill, D. B., S. M. Horvath, and F. N. Craig. Response to exercise as related to age. J. Appl. Physiol. 12:95 (1958).
8. Green, J. A., and B. Balke. The effect of physical conditioning on functional and metabolic reserves. School of Aviation Medicine, USAF, Report. (In preparation)